

AGN Variability from X-rays to Radio Waves
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Optical Variability of the Three Brightest Nearby Quasars

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Abstract.

We report on the relative optical variability of the three brightest nearby quasars, 3C 273, PDS 456, and PHL 1811. All three have comparable absolute magnitudes, but PDS 456 and PHL 1811 are radio quiet. PDS 456 is a broad-line object, but PHL 1811 could be classified as a high-luminosity Narrow-Line Seyfert 1 (NLS1). Both of the radio-quiet quasars show significant variability on a timescale of a few days. The seasonal rms V-band variability amplitudes of 3C 273 and PDS 456 are indistinguishable, and the seasonal rms variability amplitude of PHL 1811 was only exceeded by 3C 273 once in 30 years of monitoring. We find no evidence that the optical variability of 3C 273 is greater than or more rapid than the variability of the comparably-bright, radio-quiet quasars. This suggests that not only do radio-loud and radio-quiet AGNs have similar spectral energy distributions, but that the variability mechanisms are also similar. The optical variability of 3C 273 is not dominated by a “blazar” component.

1. Introduction

It is well known that all AGNs vary, but there are many unanswered questions. Here we just address the question of whether different types of AGN vary in the same manner. Two of the obvious ways in which AGNs differ among themselves are:

- (1) Radio-loudness and
- (2) “Eigenvector 1” – a correlated set of properties of which the width of the broad lines is the best known (“Narrow-line Seyfert 1s” = NLS1s, represent one extreme of eigenvector 1). Eigenvector 1 is widely believed to be a function of accretion rate.

Specific questions to consider are: (a) do bright radio-quiet AGNs vary as much in the optical as radio-loud AGNs of comparable brightness? and (b) do high-accretion-rate AGNs vary as much in the optical as low-accretion-rate AGNs of comparable luminosity? The conventional wisdom has been that radio-loud quasars show higher amplitude optical variability than radio-quiet ones because there is a contribution of a jet-related, non-thermal component in the optical (a “blazar” component). There have been some indications that NLS1s (widely considered to be high-accretion-rate AGNs) vary less in the optical (see Klimek, Gaskell, & Hedrick 2006), although NLS1s are known to vary more in soft X-rays.

2. Different AGNs have similar continuum shapes

The spectral region showing the greatest and most rapid variability is the hard to observe extreme ultraviolet (EUV) to soft X-ray region. Because of the observational difficulties the flux in this “EUV gap” has to be extrapolated from the observed ultraviolet and X-ray fluxes on either side of the gap. The observed continuum shapes on both sides of the gap show considerable object-to-object variations, and these differences are sufficiently large that they have led many to postulate that there are fundamental differences in how the energy is generated. For example, Eracleous & Halpern (1994) suggested that radio galaxies might be powered by ion-supported tori. However, the *observed* optical-UV continuum is heavily influenced by intervening matter. In Gaskell et al. (2004) and Gaskell & Benker (2005) we demonstrate that the main differences in the spectral-energy distributions (SEDs) of AGNs are consistent with *reddening differences*. After allowance for reddening, we get the surprising result that, at least for the AGNs we consider, AGN SEDs from the near IR to $\sim 1200 \text{ \AA}$ are *indistinguishable* for all classes of AGN and for all luminosities, masses, and Eddington ratios.¹

2.1. The three brightest nearby quasars

Given that the SEDs of all AGNs seem to be indistinguishable after reddening corrections, the next question is: is the *variability* also the same? To partially address this question we have been looking at the variability of the three brightest nearby quasars: 3C 273, PDS 456, and PHL 1811.

3C 273 ($z = 0.158$, $M_V = -26.6$), is the brightest, nearest, and best-known, radio-loud quasar. It has broad lines. It is a well-known variable and its light curve has been well studied for decades. The other two quasars are more recently discovered, nearby, radio-quiet quasars with luminosities comparable to 3C 273. PDS 456 ($z = 0.184$, $M_V = -26.9$) is a radio-quiet analog of 3C 273 (Torres et al. 1997; Simpson et al. 1999). It has broad lines like 3C 273. PHL 1811 ($z = 0.192$, $M_V = -25.9$) is a narrow-line Seyfert 1 quasar (Leighly et al. 2001). Figs. 1 and 2 show V-band light curves of PDS 456 and PHL 1811 from CCD observations were made with the 0.4-m telescope at the University of Nebraska’s Lincoln Observatory. The observing and measurement procedures were as described in Klimek, Gaskell, & Hedrick (2004).

We can characterize the long-term variability by simply determining the rms fluctuations for single observing seasons. For 3C 273 we determined the rms fluctuations from 11 seasons of CCD photometry given in Türler et al. (1999). We summarize our results in Table 1.

It can be seen from Table 1 that there is no evidence for the two, bright, radio-quiet quasars to be less variable than the bright, radio-loud quasar 3C 273. When considering the rms variability of PHL 1811 it is interesting to note that, for 3C 273, the rms seasonal variability has exceeded ± 0.100 mag. only once over the past 30 years. Even if we had not happened to catch the low state of PHL 1811 around JD 2452895, its seasonal rms variation is still similar to that of 3C 273.

¹it remains to be seen how true this is for AGNs with the very lowest Eddington ratios.

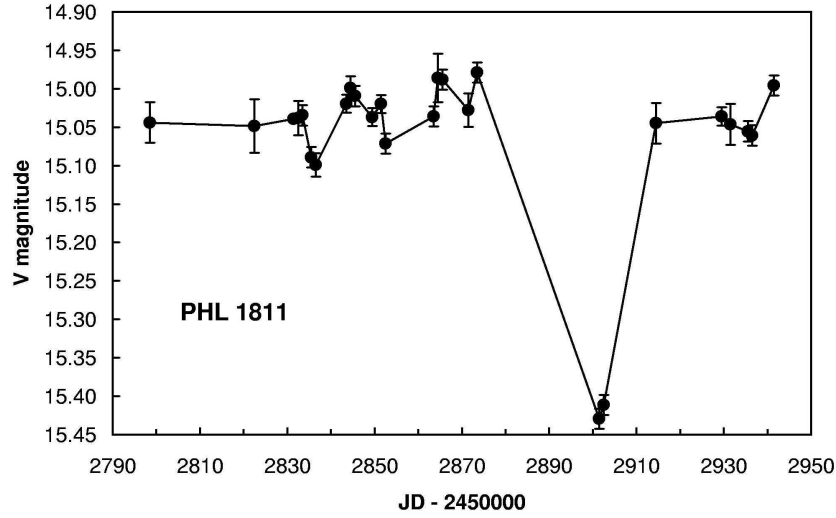


Figure 1. V-band light curve for PHL 1811 in 2003. The lines connecting the points are only to guide the eye.

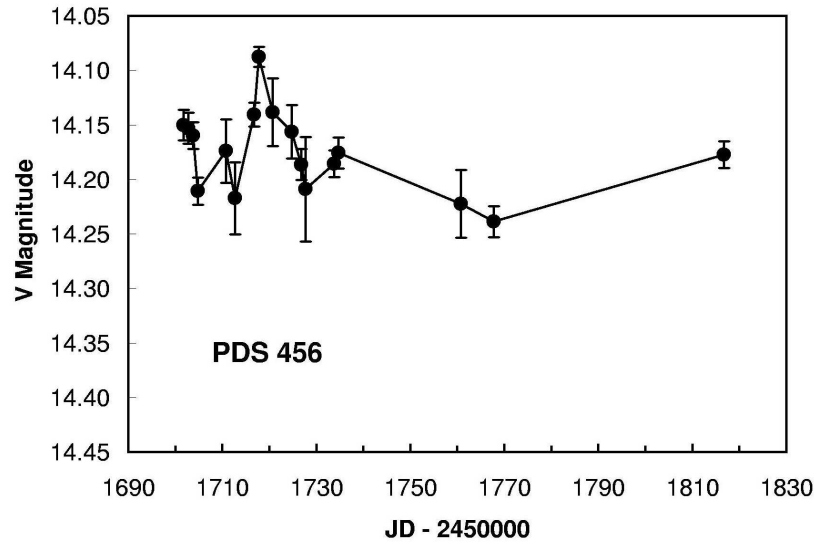


Figure 2. V-band light curve for PDS 456 in 2000.

Table 1. Seasonal RMS Variability.

Object	Year	RMS (mag.)
PDS 456	2000	± 0.042
	2003	± 0.036
PHL 1811	2003	± 0.109
3C 273	11 seasons	± 0.042

It is also interesting to compare short-term variability properties. Although we did not often obtain daily sampling, for PDS 456 we did find several $\sim 10\%$ variations in the V -band over 24 hour periods at the 99% confidence level over three observing seasons even without attempting to subtract out any host galaxy component. PDS 456 is also an extreme X-ray variable with factor of two changes in 8 hours (Reeves et al. 2002). Thus, a bright, radio-quiet quasar *can* show strong short-term variations in both the X-ray and optical regions. PHL 1811 also shows significant variations over a day or two, although the amplitude of short-term variability is not as great for PHL 1811 as for PDS 456.

There is additional evidence that the short-term variability of various classes of AGNs are similar. Low-luminosity NLS1s show a similar occurrence of optical sub-diurnal variability to non-NLS1 AGNs (Klimek, Gaskell, & Hedrick 2004, 2006). And for radio-loud and radio-quiet AGNs, Stalin et al. (2004) found similar occurrences of optical sub-diurnal variability.

3. Conclusions

Based on our photometry, it seems that, on both long and short timescales, the conventional wisdom that radio-loud quasars should be more variable is not correct, and there is no evidence that the optical variability is fundamentally different for different classes of AGNs.

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